Exhibit A

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TECHNICAL DISCUSSION

The scientific and engineering background underlying the ultimate objectives of the program for which this proposal is submitted as a feasibility investigation effort is divided into two problem areas:

(1) The design and development of a straightforward, safe, and reliable liquid bipropellant propulsion system having the unique characteristics of minimum exhaust gas IR radiation.

(2) The ultimate development of IR detector systems capable of locating an IR source having a specified magnitude of IR emission.

The state-of-the-art in the field of bipropellant liquid rocket engines is at the level where straightforward engineering approaches will yield a reliable and operational rocket system only with the use of non-cryogenic pure chemicals in the propellant system. This statement, as set forth, is related to the rocket hardware only. The problems associated with tankage for hypergolic propellants is the only risk area from the standpoint of eventual development of safe and reliable airframe design and operation. This is primarily a specification problem involving myriad engineering details and is not associated with any basic physical phenomena other than the fact that hypergolic liquids are intensively reactive chemically and hence straightforward and rigorous means must be followed in the development of the tanks required to contain the propellants.

In the rocket engine field there have been many intuitive arguments advanced concerning the specific properties of certain propellant systems and how the properties enhance the safety and reliability characteristics of

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the ultimate rocket propulsion system. One among these characteristics purporting to enhance safety and reliability standards has been the proposed use of propellant systems having narrow O/F ignition limits. It seems to be coming increasingly clear that this concept is not on a firm scientific footing as once proposed and that the safety standards (which means explosion hazard) of the propellant system are more firmly enchanced by the use of chemicals which are intensely hypergolic, the more so the better. The property of hypergolicity insures acceptable combustion stability standards with relatively unsophisticated injector designs, meaning quality of propellant spray structure. In addition, the accumulation of fuel or oxidizer in the propellant chamber constitutes less of a hazard, which fact has been demonstrated by many research and development projects in the field of chamber design where ever these projects have used chemicals which are extremely hypergolic.

The use of hypergolic propellants admittedly constitutes a problem from the standpoint of tankage and propellant handling equipment in confined volumes such as in an airframe fuselage. This, however, is an engineering problem which can be handled in an engineering manner in comparison with instability problems in chambers using unsaturated hydrocarbon fuels or freezing problems in propellant handling equipment using cryogenic oxidizers.

Consequently, it seems apparent that second-generation liquid rocket engine systems seem headed for the use of hypergolic, storable, non-cryogenic liquid propellants. It seems further apparent that such systems should be used in the first attempts, at this stage of state-of-the-art, in rocket powered, manned aircraft be this aircraft an air-cruising vehicle or space vehicle.

There has been a sad neglect of storable liquid propellant systems, which error on the part of the Military Services is now being realized. For some time, there has been available the propellant system which all experienced workers in the field recognize as the most effective system for bipropellant liquid rocket applications. This system is generalized as a large class of organic and inorganic amine fuels with nitric acid. The system which shows today the greatest degree of development potential or operational status is nitric acid with either hydrazine or unsymmetrical dimethyl hydrazine. It is apparent now that the achievement of the highest degree of safety and reliability of liquid rocket systems will be operationally achieved with the acid-based, hypergolic systems using either of the above two fuels or, alternatively, mixed amine (MAF) propellants.

The second important problem area is associated with the emission of radiant energy by the exhaust gas jet in the IR spectrum. Operational systems have in the past used carbon bearing fuels which, when used with either acid or LOX, give rise to long tail-plumes containing incandescent carbon particles. The exhaust gases in such rockets, in addition to containing the carbon particles, contain carbon dioxide, water vapor, and various free radicals such as OH. The emissivity of the incandescent carbon particles, being close to that of black body radiation, is 10,000 times greater in kilowatts per square centimeter at 6000° Kelvin than the emissivity of the gaseous products of combustion. The inference in such a comparative figure, and the fundamental concept that should be followed, is that there should be no carbon atoms used in the propellant systems in order to minimize IR radiant energy. It is proposed that such a step be followed by the use of pure hydrazine, N_2H_4, and that this be qualitatively demonstrated by the use of UDMH, $(CH_3)_2NNH_2$. In addition to the use of such a fuel, it is postulated that if a rocket chamber has a large L* and an over expanded nozzle for space application, that these two steps will, respectively, establish completion of combustion before the gases enter the exhaust nozzle and reduction of the exhaust gas static temperature to values where recombination of dis-associated products of combustion will have been totally effected before the exhaust gas exits from the nozzle discharge. In this last case, the radiation which is known to occur from dissociated gases will be minimized and perhaps eliminated.

This discussion has been qualitative insofar as concerns those measures which may be taken from the engine standpoint in order to minimize IR emission. However, it should be realized that over-emphasis in proposed solutions pertaining to the emission problems may well occur if due attention is not given to the state-of-the-art of IR detection from ground stations particularly in the forward hemisphere. It is well known that current projects are in hand designed to achieve very sensitive IR detectors in space. That is, the detectors must be in space as well as the IR source. Under such circumstances workers in the field hope to achieve lock-on distances between 100 and 1000 miles. However, for ground-located IR detectors, the IR radiation from high temperature CO_2 and H_2O molecules in space are attenuated by the earth's atmosphere such that it seems next to impossible to locate a high altitude IR source of the order of magnitude and general physical size that this project is associated with. Hence, the statement that it is possible that too much attention can be paid to the engine side of IR radiation and not sufficient attention to the detector side. The ultimate solution to this problem is one which is partially defined by missions and roles.

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TO

BUREAU OF AERONAUTICS

EXHIBIT "B"
Ref: 58T-0458/1111

SCOPE OF WORK

For a period of six (6) months the Contractor shall provide services for the execution of a systems feasibility study directed towards the ultimate development of a throttleable liquid bipropellant rocket engine capable of generating propulsive thrust under steady state operating conditions. Certain unique capabilities of the ultimate hardware system are required by the end-point application. It will be the purpose of this contract to explore the feasibility of realizing these ultimate system capabilities.

The feasibility study will consist of the following specific items of work:

Item I

The Contractor shall conduct a preliminary design study of a liquid rocket propulsion system using hypergolic propellants, the system having a throttleable thrust range of approximately 4:1. The maximum thrust shall be approximately 5,000 lbs. The design study, done in concert with the weapons systems manufacturer designated by the Bureau of Aeronautics, will include examination of all pertinent subsystems for the reliable and safe operation of a primary hypergolic bipropellant propulsive system. This study shall include examination of propellant performance, component and subsystem weights, propellant utilization as determined by tankage requirements, propellant handling turbo-machinery, control requirements, etc. The objective of this preliminary design study will be to determine the logical course of design for the ultimate development of the prototype system and shall include items of projected cost and time requirements.

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SCOPE OF WORK
(Continued)

Item II

The ultimate prototype system to be delineated in the preliminary design study to be accomplished under Item I above must possess characteristics not yet incorporated in existing operational liquid rocket engine sytems although these desired characteristics are within state-of-the-art possibilities. In order to increase the validity of the work to be accomplished under Item I, the Contractor shall perform an experimental program using a duplicate of a water-cooled chamber that the Contractor has on hand having been previously developed for other experimental investigations. This duplicate chamber is the Hughes R19 rocket engine capable of a maximum thrust of 600 to 1000 pounds. The experimental program shall consist of the following main investigation areas:

A. The Contractor shall investigate the feasibility of ultimately achieving a regeneratively cooled chamber capable of at least 30 minutes operation without burnout. Preliminary demonstration of this ultimate capability shall be accomplished by operation of the Contractor's R19 water-cooled rocket engine at the 600 pound thrust level for run durations of approximately five (5) minutes each thus assuring achievement of temperature equilibrium. These endurance demonstration runs shall not be conducted separately but rather shall be included with other measurements such as performance (I_{sp}), IR emission, and stop-start cycling which are specific items in this scope of work as detailed below. The total accumulated operating time shall be a minimum of 50 minutes.

SCOPE OF WORK
(Continued)

B. The Contractor shall perform thrust and propellant flow measurements in the R19 chamber in order to evaluate sea-level I_{sp} for two fuels used with RFNA (commercial grades) as the oxidizer. The two fuels shall be hydrazine and unsymmetrical dimethyl hydrazine (UDMH).

C. The Contractor shall incorporate provisions within the chamber test system in order to demonstrate start-stop-restart chamber operation. These provisions shall include only conventional valve systems and shall not include any provisions or simulated provisions for propellant feed which could pertain to the ultimate prototype system. The number of start-stop-restart cycles shall be incorporated with the other specific items of this Scope of Work (approximate number, 10).

D. The Contractor shall investigate the important problem area of jet exhaust lateral IR emission with the objective of establishing the feasibility of designing an ultimate prototype rocket chamber substantially free of radiant energy, in lateral directions, in the IR band as detectable by ground-located IR detectors. The investigation of this problem area will be conducted by two (2) steps:

(1) The R19 chamber will be run with hydrazine (a carbon free molecule) and red fuming nitric acid (RFNA). The chamber, which shall be equipped with a sea-level nozzle, will have added to it a cylindrical shield of the same length as the applicable space nozzle surrounding the

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EXHIBIT "B"
Ref: 58T-0458/1111

SCOPE OF WORK
(Continued)

existing exhaust gas jet. Measurements of IR emission normal to the jet will then be made downsteam of the shield. The results of these measurements will be extrapolated to space conditions pertaining to the use of the space nozzle.

(2) The test outlined above will be repeated using unsymmetrical dimethyl hydrazine (UDMH) in order to establish a basis of comparison of similar fuels with and without carbon atoms.

Item III

The Contractor shall submit in triplicate informal monthly letter progress reports outlining the results of the investigation for the previous month and the proposed future steps for the succeeding month. This monthly report will be submitted to the Bureau of Aeronautics, Code AE-511, Attention: A. D. Struble.

Item IV

quadruplicate

The Contractor shall submit in ~~triplicate~~ an [redacted] final report covering the work of Items I and II above. Delivery shall be made in accordance with Item III.

One of these reports will be a reproducible copy.

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EXHIBIT "C"
Ref:58T-0458/1111

DELIVERY SCHEDULE

Item I	Three months from date of go ahead
Item II	Six months from date of go ahead
Item IV	Monthly
Item V	Concurrent with I and II

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TO
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EXHIBIT "D"
Ref: 58T-0458/1111

GOVERNMENT FURNISHED PROPERTY

Item	Amount Pounds	
Hydrazine, N_2H_4	3,000	40 min
Unsymmetrical dimethyl hydrazine $(CH_3)_2NNH_2$	700	10 min
		50 min total
RFNA	5,000	

$\frac{5}{2} \cdot 3700 = 9250$ (1850)
500
9750.00

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TO
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ATTACHMENT "A"
REF: 58T-0458/1111

COST BREAKDOWN

Item I

Engineering Analysis	500 hrs @ $5.07	$ 2,535.00
Publications	50 hrs @ $3.58	179.00
		$ 2,714.00
Overhead @ 139%		3,772.46
		$ 6,486.46
Travel		500.00
		$ 6,986.46
G & A @ 9.9%		691.66
		$ 7,678.12
Fixed Fee @ 6%		460.69
	Total	$ 8,138.81

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TO
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ATTACHMENT "A"
58T-0458/1111

COST BREAKDOWN
(continued)

Items II, III, IV

Engineering	270 hrs @ $5.07	$ 1,368.90
Test	1800 hrs @ $3.78	6,804.00
Shop	1400 hrs @ $3.09	4,326.00
Publications	200 hrs @ $3.58	716.00
		$13,214.90
Overhead @ 139%		18,368.71
		$31,583.61
Material		4,000.00
		$35,583.61
G & A @ 9.9%		3,522.78
		$39,106.39
Fixed Fee @ 6%		2,346.38
		$41,452.77

41 452.77
8 138.81
9 750.
$ 59,341.58

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